PROPOSAL FOR TOPIC APPROVAL TO BE SUBMITTED TO THE UNIVERSITY OF MUMBAI FOR THE Ph.D. DEGREE IN THE SUBJECT OF CHEMISTRY

Title of the topic	:	An environmentally benign and sustainable approach to the potential utilization of carbonaceous or other waste.
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DATE of SUBMISSION - 21/04/2023

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1. **Title:**

"An environmentally benign and sustainable approach to the potential utilization of carbonaceous or other waste."

2. **Aim of Study:**

The objective of this research is to modify different types of carbonaceous materials including recovered carbon black, biochar, and carbon black from various sources. The aim is to improve the surface morphology, structure, and chemical activity of these materials by using a range of purification and modification techniques. The prepared materials will be comprehensively characterized using advanced analytical techniques, and their performance will be evaluated in diverse applications such as waste water treatment, energy storage, and as mechanical strength enhancers in rubber, polymer, and plastic end products etc. The ultimate goal is to enhance the properties of recovered carbonaceous materials for their potential applications in industries such as rubber and tire manufacturing, energy, and environmental remediation etc.

3. **Objectives of Study:**

Here are some objectives for the research proposal:

- To investigate the effectiveness of various purification and modification techniques for enhancing the surface morphology, structure, and chemical activity of different carbonaceous materials such as recovered carbon black, biochar, carbon black etc.
- To evaluate the impact of incorporating different functional groups on the properties of the modified carbonaceous materials.
- To comprehensively characterize the prepared materials using advanced analytical techniques spectroscopy and microscopy etc.
- To evaluate the performance of the modified carbonaceous materials in diverse applications such as waste water treatment, energy storage, and as mechanical strength enhancers in rubber, polymer, and plastic end products and other application.
- To compare the performance of the modified carbonaceous materials to existing commercial products.
- To assess the economic viability with commercial carbon black materials against modified carbonaceous materials in industrial applications, considering factors such as cost, availability, and performance.

4. Study Background (Literature Review) and Significance of Study:

4.1 Literature Review:

As the global population continues to grow, the production of waste increases exponentially. In addition, the current linear economy model of "take, make, and dispose" has led to an accumulation of waste that negatively impacts the environment and human health. The literature review for this research proposal would focus on previous research that has investigated the modification of carbonaceous materials like recovered carbon black[1] [2], biochar[3], and carbon black[4], coal filler[5] etc for various applications, including waste water treatment, energy storage, and mechanical strength enhancers in rubber, polymer, and plastic end products. It will also highlight the potential benefits of using recovered carbonaceous materials in industrial applications, such as reducing the environmental impact of waste disposal and promoting sustainable development.

Carbonaceous waste materials, such as biomass, organic waste, and carbon-rich industrial waste, are of particular interest due to their potential as alternative sources of energy and raw materials.

Mr. Rajender S. Varma et. al' in his research provides a literature review on the potential of biopolymers such as cellulose, chitin, and chitosan, which are abundant in the biosphere and possess desirable traits such as biodegradability and renewability. The research highlights the advantages of these basic polysaccharides in generating chemical entities with unique functional properties, particularly in the field of nanotechnology. The research presents examples of sustainable chemical transformations and environmental remediation using these biopolymers, as well as traditional biomass-derived platform chemicals as a potential source of renewable feedstocks. The aim is to produce sustainable products that reduce the dependence on fossil fuel-derived chemicals.[6]

Khanal, et. al research journal discusses Anaerobic Digestion (AD), which is a technology for waste remediation, bioenergy generation, and greenhouse gas reduction. The study highlights that there has been a paradigm shift in Anaerobic Digestion technology beyond biogas and provides insights into recent advances such as anaerobic biorefinery, chain elongation, treatment of micropollutants, and more. The study also provides a brief summary of the 53 manuscripts included in the special issue, which can serve as a valuable resource for Anaerobic Digestion researchers to identify future research directions.[7]

Py et al. research explores the gradual modification of pore sizes in activated carbon through successive widening cycles, which involves molecular oxygen sorption and carbonization. The study found that the resulting microporosity has better pore size distribution and covers a wide range of porous textures dependent on the initial material and activation. The study observed a gradual increase in mean pore size and microporous specific volume in pitch-based and coconut activated carbons, respectively, while a commercial coconut carbon molecular sieve increased its microporous specific volume without changing its mean pore size. These results were used to test a recently proposed textural model of activated carbon porosity. Activated carbon porosity tailoring by cyclic sorption/ decomposition of molecular oxygen.[8]

F. Heras et al. his research focuses on the use of cyclic activation as a method to control porosity development in the preparation of activated carbons and other porous carbon materials. The method involves controlled oxidation of a starting carbon followed by thermal desorption, resulting in burn-off and porosity development. The study aims to investigate the effect of different oxygen chemisorption and desorption temperatures on the success of cyclic activation and to determine the optimal conditions for achieving regular pore widening. The research will contribute to the development of a controlled and efficient method for porosity development in porous carbon materials.[9]

Carbon-rich industrial waste, such as coal ash, fly ash, and waste carbon dioxide, can also be utilized in a variety of ways. For example, coal ash and fly ash can be used as raw materials for cement and concrete production, while waste carbon dioxide can be captured and utilized in carbon capture and utilization (CCU) technologies, such as the production of biofuels and chemicals.

The article by M.A. Al-Ghouti et al. explores the extraction and separation of metals, specifically vanadium and nickel, from fly ash produced in Jordan. The authors developed a modified Akita's procedure to selectively elute and precipitate Ni and V from the fly ash, achieving high ratios of Ni/V and V/Ni in the final precipitate. This study provides a promising method for recovering valuable metals from waste material.[10]

Eterigho-Ikelegbe et al. in his review research provides an overview of the development of polymer composites using coal as a filler feedstock, which is of growing interest due to the demand for non-traditional specialized materials. The study explores the polymeric nature and macromolecular structure of coal, and reviews published experimental studies on coal as a filler in polymeric composites. The study suggests the need for further modelling and simulation studies to predict the influence of processing parameters on composite performance, and

positive results could lead to large-scale application of coal as a filler in polymer composites beyond the laboratory scale.[11]

Franco Cataldo in his research focuses on the properties of carbon black (CB) used as a reinforcing filler in rubber products. Pyrolytic carbon black (CBp), obtained from waste tires, contains the original CB along with inorganics and sulphur, making it a potential substitute for CB in rubber applications. However, CBp has been found to have limitations in some rubber applications, including reduced tensile strength, tear strength, and hardness, due to the presence of inorganics. Post-treatment processes have been proposed to overcome these limitations.[12]

P. Ariyadejwanich et al. in his research explores the production and characteristics of activated carbons made from waste tires. The rubber from waste tires was carbonized and then activated with steam, resulting in mesoporous activated carbons with high mesopore volumes and BET surface areas. Treatment with HCl further improved the porous properties, resulting in even higher mesopore volumes and BET surface areas. The prepared carbon showed a slightly lower phenol adsorption capacity but a significantly larger dye adsorption capacity than a commercial carbon due to its larger mesopore volume.[13]

The study by A. Undri et al. explores the correlation between experimental conditions of Microwave Assisted Pyrolysis (MAP) of tires and the characteristics of the resulting char. The study suggests that MAP is a promising method for recycling waste polymeric materials due to their high microwave absorbing capacity. The results indicated that MAP variables did not significantly affect the characteristics of the char, which contained a high proportion of amorphous carbon and inorganic compounds from tire additives. The XRD analyses showed different crystalline forms of ZnS due to the amount of waste tires employed. This study provides valuable insights into the potential of MAP as a waste tire recycling method.[14]

4.2 Significance:

Industrial applications: Carbonaceous materials such as recovered carbon black, biochar, and carbon black have a wide range of potential industrial applications, including in rubber and tire manufacturing, energy storage, and environmental remediation and catalysis etc.

The research aims to enhance carbon-based materials for various industrial applications. In energy storage, modified carbon materials could be used in batteries and supercapacitors due to their high surface area and conductivity. Recovered carbon materials could be improved for use as fillers in rubber and tire manufacturing to enhance durability and performance[15]. Additionally, modified carbon materials could also be used to enhance the mechanical strength

of plastic end products, reducing the need for traditional fillers and improving environmental impact.

Environmental significance: The proposed research aims to explore sustainable and environmentally friendly approaches for utilizing waste carbonaceous materials to develop high-value products, leading to waste reduction, improved mechanical properties, and potential for environmental remediation. Additionally, it seeks to investigate the economic and social implications of waste utilization and circular economy models for sustainable and equitable development.

5. **National Status:**

Extracting the national status from research and journals related to the above-mentioned research objective could involve identifying the current status of carbonaceous material utilization and waste management practices in the country of interest. Here are some possible examples:

In India, carbon black is a by-product of the petroleum industry and is mostly used in the rubber and tire manufacturing sector. However, the production and disposal of carbon black have been identified as sources of environmental pollution, and there is a need for sustainable waste management practices that promote the circular economy concept.

In their research, Mr. Prathmesh Anerao et al. discuss the production and diverse applications of biochar, which include environmental remediation, water purification, catalysis, tissue engineering, and more. They also emphasize the importance of modification of biochar through physical and chemical treatments to achieve specific applications and enhance its quality. The review focuses on recent developments in physical treatment processes of biochar, highlighting opportunities, challenges, and future prospects of this cost-effective and environmentally friendly method.[16]

M. Sagar et al.in his research examines the environmental concerns associated with end-of-life (EOL) tyres and the potential of pyrolysis as an eco-friendly process for recycling. Specifically, the study investigates the effect of recycled carbon black (rCB), obtained from pyrolysis of EOL tyres, on the properties of ethylene propylene diene rubber (EPDM). The rCB was characterized and incorporated into EPDM formulations, both alone and in combination with N550 carbon black, and the physico-mechanical properties of the resulting vulcanizates were studied. The study finds that the reinforcing effect and cross-link density of rCB-filled vulcanizates were slightly inferior to those filled with conventional carbon black, but the breaking mechanism followed the rubber chain detachment from the surface mode.[17]

Virendra Kumar Yadav et al. conducted research on the use of fossil and renewable fuel sources for electricity production, highlighting the depletion of reserves and pollution caused by the dependence on fossil fuels. The research focuses on coal fly ash (CFA), a major issue due to its large production in thermal power plants. While almost half of the generated CFA is utilized in various forms, the remaining half remains unused, leading to various types of pollution. The authors emphasize the need for efficient and sustainable CFA management approaches. The review provides a detailed description of CFA-based thermal power plants, fly ash production, and utilization. It also covers the current and emerging applications of CFA.[18]

Dilip kumar Akhil, Divya Lakshmi, & Ashok kumar Kartik conducted research on the need for advanced remediation techniques due to increased industrial and domestic activities causing pollution, global warming, and resource depletion. Biochar synthesized from waste materials is a low-cost and eco-friendly material for remediation, but raw biochar is not efficient enough. To improve biochar properties, various techniques such as ultrasonication, metal impregnation, surfactant modification, microwave, electrochemical, and plasma treatment have been used. Engineered biochar exhibits high contaminant removal efficiency, wide pH tolerance, and high specific surface area. For example, modified cornstalk biochar has a mercury adsorption capacity of 269.4 mg/g, and the use of magnetic biochar allows for a β-estradiol adsorption capacity of 98.8 mg/g. Engineered biochar can be an eco-friendly soil amendment and an effective tool for recovering contaminants from water systems.[19]

In India where waste management infrastructure and practices are often inadequate or non-existent, there is increasing interest in the potential of waste utilization to address environmental and social challenges. For example, in India, the government has launched several initiatives to promote waste-to-energy technologies, such as biogas production from organic waste and waste-to-energy plants that generate electricity from municipal solid waste. Overall, the national status of carbonaceous material utilization and waste management practices varies across different countries and regions, and there is a need for more sustainable and environmentally friendly approaches to their utilization.[20]

6. International Status:

The international status of sustainable and environmentally-friendly utilization of carbonaceous and other waste materials varies across different regions, depending on factors such as waste generation rates, waste management practices, and policy frameworks. However, there is a global trend towards recognizing the potential of waste utilization to promote resource efficiency and reduce negative environmental impacts.

In China, biochar has been widely used as a soil amendment for its ability to enhance soil fertility and reduce greenhouse gas emissions.

As per researcher Jun Meng et. al China explores his research for the use of biochar produced from straw for improving soil properties. It analyzes current developments, identifies knowledge gaps, and proposes production and modification of biochar for enhanced fitness. The authors recommend long-term field studies and suggest prospects for future development, including a standard system for straw biochar returning and a biochar-based agricultural production model. The study provides valuable insights and recommendations for future research in this field.[21]

A study conducted by Fan Yang, Shuai Liang, Haipeng Wu, and Chengyu Yue aimed to address the issue of limited wide application of pyrolysis carbon black (CBp) from waste tires, due to its poor reinforcing ability and low additional value. To upgrade CBp, the authors used ball milling to hybridize it with micro fibrillated cellulose (MFC). This resulted in a CBp/nanocellulose hybrid (CNCH) with a bead-chain-like morphology, where small CBp particles were attached firmly to cellulose nanofibers. CNCH exhibited higher reinforcing ability compared to CBp and ball-milled CBp (mCBp), attributed to its unique morphology, fine dispersion, interlocking effect, and improved interface interaction with natural rubber (NR) molecular chains. NR reinforced with CNCH had low hysteresis and higher antiabrasion ability, making CNCH a promising reinforcing filler for tires. The upgrading process is simple, eco-friendly, and suitable for industrial applications. This research provides a theoretical basis and technical instruction for the use of CBp in tires, accelerates the industrialization of pyrolysis, and helps resolve the black pollution problem.[22]

In the United States, recovered carbon black has gained attention as a sustainable alternative to virgin carbon black, particularly in the tire manufacturing industry. However, there are still technical and economic challenges associated with its production and utilization, and more research is needed to optimize the purification and modification techniques for different types of recovered carbon black.[23]

Gómez-Hernández et. al. in his research study explores, a simple and cost-effective method for preparing carbon black (CB) nanoparticles from waste tires is reported. The yield of recovered CB nanoparticles (around 22 nm) was approximately 81%, and the material showed good thermal stability and conductivity, forming chain-like agglomerates. The product was partly oxidized and fully characterized by various techniques. This preparation method offers a viable alternative for reducing waste tires and their environmental impact, while producing high-

quality CB nanoparticles suitable for various applications, including batteries, sensors, catalysis, pigments, concrete, and plastics.[24]

Kulawong, S et al research in his work aimed to prepare sodium and proton forms of mordenite zeolite using carbon as the second template. Both forms were characterized for their structure, morphology, and textural properties. Structural defects and acidity were evaluated using NMR and NH3-TPD. Fe(NO3)3·9H2O was impregnated onto both forms, with XANES analysis indicating Fe2O3 as the main form. Catalytic testing showed improved conversions and selectivities.[25]

Overall, there is a growing international recognition of the potential of waste utilization to promote sustainable development and reduce negative environmental impacts. The adoption of sustainable waste management practices, including waste utilization, is being promoted by international organizations, governments, and civil society groups in different regions of the world. Further research, investment, and supportive policy frameworks are needed to fully realize the potential of waste utilization on a global scale.

7. **Study Hypotheses:**

Possible study hypotheses for "An environmentally benign and sustainable approach to the potential utilization of carbonaceous or other waste" could include:

- The utilization of carbonaceous or other waste materials can provide a sustainable alternative to conventional fillers, chemicals, fuels and can reduce greenhouse gas emissions. The incorporation of functional groups onto the surface of recovered carbon black, biochar, and carbon black will improve their chemical activity and enhance their performance in various applications.
- The recovered carbonaceous materials obtained from various sources will show different performance in the evaluated applications due to variations in their structure, morphology, and chemical composition
- The purification and modification techniques could be used to improve the surface morphology and structure of carbonaceous materials, leading to enhanced properties.
- By implementing environmentally benign waste utilization strategies, it is possible to mitigate negative environmental impacts associated with waste generation and disposal. The utilization of carbonaceous or other waste materials can contribute to the circular economy by promoting resource efficiency and reducing the reliance on virgin materials.

8. Study Rationale:

The rationale for this research is to address the issue of waste management and resource utilization in a sustainable manner. Carbonaceous materials such as recovered carbon black, biochar, and carbon black are generated as waste from various industrial processes and are often disposed of in landfills, causing environmental pollution. However, these materials have the potential to be valuable resources if their properties can be enhanced for various applications. Therefore, this research aims to explore and develop methods to modify and improve the properties of carbonaceous materials, and evaluate their performance in various applications.

Examples of the rationale for this research include:

With the increasing demand for rubber and tire products, there is a growing need to find sustainable alternatives to traditional carbon black, which is derived from fossil fuels. Recovered carbon black, which is obtained from used tires, can be a potential substitute for traditional carbon black if its properties can be enhanced for use in rubber and tire manufacturing.

Biochar is a by-product of biomass pyrolysis and has been shown to have potential applications in environmental remediation and soil amendment. However, its properties and performance in these applications can be improved through modification techniques, leading to more efficient and effective use of this resource.[3]

Carbon black is widely used in energy storage devices such as batteries and supercapacitors. However, its performance can be improved by incorporating functional groups and modifying its surface morphology, leading to increased energy storage capacity and longer cycle life.[4,26]

9. Research Methodology:

To achieve the objectives of this PhD research, a mixed-methods approach will be employed, consisting of both qualitative and quantitative research methods. The methodology will include the following steps:

9.1 Literature Review:

A comprehensive literature review will be conducted to provide a theoretical foundation for the research, including an overview of carbonaceous and other waste materials, current waste management practices, existing technologies for waste utilization, sustainable and environmentally benign approaches to waste utilization, and criteria for evaluating the sustainability and environmental impact of waste utilization approaches.

9.2 To study Structural and surface morphology of carbonaceous and other waste materials.

The structural and morphological characterization of carbonaceous materials is an essential aspect of this research project. The following are some of the advanced analytical techniques that can be used to comprehensively characterize the prepared materials:

Analytical techniques such as SEM, TEM, XRD, FTIR, Raman spectroscopy, BET surface area analysis, TGA, and NMR spectroscopy can be utilized to fully understand the structural and morphological characteristics of carbonaceous materials, allowing for optimization of their properties for various applications. The choice of techniques will depend on the specific research questions being addressed and the properties of the materials being studied.

9.3 Design of experiment:

Based on the research objectives, the following research methodology can be adopted

Sample Preparation: Samples of recovered carbon black, biochar, and carbon black from different sources will be collected and prepared for further analysis.

Purification and Modification Techniques: A range of purification and modification techniques will be employed to enhance the surface morphology, structure, and chemical activity of the materials. These techniques may include chemical treatment and modification, physical treatment oxidation, pyrolysis, and hydrothermal treatment microwave treatment, and/or sonication etc. By this virtue various functional groups will be incorporated into the materials to improve their properties. These functional groups may include carboxyl, hydroxyl, and amino groups etc

Characterization of modified materials: The prepared materials will be comprehensively characterized using advanced analytical techniques such as Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), scanning electron microscopy (SEM), thermogravimetric analysis (TGA), and surface area analysis etc.

Performance Evaluation: The performance of the prepared materials will be evaluated in diverse applications such as waste water treatment, energy storage, and as mechanical strength enhancers in rubber, polymer, and plastic end products, catalysis etc.

Data Analysis: The data collected from the characterization and performance evaluation of the materials will be analyzed using statistical tools to establish correlations between the properties and performance of the materials.

10. Statistical Plan:

Table: Statistical Plan

Period of study	Achievable Targets
1st Six months	Literature survey and course work
2nd Six months	Preliminary screening and data collection
3rd Six months	Finalization of route of reaction, characterization of compounds and screening of application
4th Nine months	Synopsis and thesis writing

11. Limitations of the Study:

Some potential limitations of the study includes ,The study focuses only few types of carbonaceous materials, which may not be representative of all the materials used in various industries.

Resource constraints: Comprehensive characterization and evaluation of the prepared materials using advanced analytical techniques may require significant different resources, which could be a limitation for the study.

External factors: The performance of the prepared materials in different applications may be influenced by external factors such as environmental conditions and operational parameters, which may not be completely controllable.

Generalizability: The results of the study may not be generalizable to all types of industries and applications, as the specific properties and requirements may vary significantly.

12. Expected Outcome of Study:

The expected outcomes of this research can include:

- Improved surface morphology, structure, and chemical activity of recovered carbonaceous materials through purification and modification techniques.
- Development of modified carbonaceous materials with functional groups to enhance their properties.
- Identification of the optimal conditions for using modified carbonaceous materials in waste water treatment, energy storage, and as mechanical strength enhancers in rubber, polymer, and plastic end products.

- Enhanced performance of recovered carbonaceous materials in different applications.
- Identification of the potential industrial applications of modified carbonaceous materials in industries such as rubber and tire manufacturing, energy, and environmental remediation.
- Contribution to the body of knowledge on the modification and purification of carbonaceous materials.
- Possibility of developing new products and technologies based on the results of this research.

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